MECHANICAL ENGINEERING Paper I

Time Allowed: Three Hours **Maximum Marks: 300**

QUESTION PAPER SPECIFIC INSTRUCTIONS

Please read each of the following instructions carefully before attempting questions

There are *EIGHT* questions divided in two Sections.
Candidate has to attempt *FIVE* questions in all.
Question Nos. **1** and **5** are compulsory and out of the remaining, any THREE are to be attempted choosing at least ONE from each Section.
The number of marks carried by a question/part is indicated against it.
Wherever any assumptions are made for answering a question, they must be clearly indicated.
Diagrams/Figures, wherever required, shall be drawn in the space provided for answering the question itself.
Unless otherwise mentioned, symbols and notations have their usual standard meanings.
Psychrometric Chart is given in Page No. 8.
Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly.
Any page or portion of the page left blank in the QCA Booklet must be clearly struck off.
Answers must be written in ENGLISH only.

SECTION—A

1. (*a*) Discuss the sources of minor losses which can take place in circular pipes. 12

(*b*) Calculate the decrease in available energy when 25 kg of water at 95°C mixed with 35 kg of water at 35°C, the pressure being taken as constant and the temperature of the surroundings being 15°C.
(Specific heat of water = 4.2 kJ/kg K) 12

(*c*) Draw a typical boiling curve for pool boiling of water at saturation temperature and atmospheric pressure, and mark each boiling regime. 12

(*d*) A diesel engine is working with a compression ratio of 18 : 1 and expansion ratio of 12 : 1. Calculate the air-standard cycle efficiency. Assume $\gamma = 1.4$. If the relative efficiency of the engine is 50% and calorific value of diesel fuel is 45000 kJ/kg, find out the specific fuel consumption of the engine in kg/kWh. If this engine has its application for DG set purpose of 500 kW rating at full-load condition and is expected to operate for two hours every day, work out the inventory requirement of diesel for next 15 days. Also work out fuel cost of diesel for 15 days period if cost of fuel per litre is ₹ 60. Make suitable assumptions if required. Consider diesel density as 0.83 kg/litre. 12

(*e*) A natural draught cooling tower used in a large cold storage plant receives water from the condenser outlet at a flow rate of 35000 kg/s and 40°C temperature. The ratio of flow rate of water to air is 1.2 : 1 in the cooling tower. Inlet condition of the air entering the cooling tower is dry-bulb temperature (DBT) of 20 °C and wet-bulb temperature (WBT) of 10 °C. Air leaves the cooling tower at DBT of 35 °C with relative humidity of 90%. For this cooling tower—

(i) draw the inlet and exit conditions of air in psychrometric chart and name the process;

(ii) determine the rate of evaporation of water in kg/s;
(iii) determine the heat carried away by the air;
(iv) determine the maximum possible temperature drop of water realizable.
[Psychrometric Chart is placed at the end] 12

2. (*a*) Glycerine is pumped at a constant rate of 20 litres/s through a straight, 100 mm diameter pipe, 45 m long, inclined at 15° to the horizontal. The gauge pressure at the lower inlet end of the pipe is 590 kPa. Verify that the flow is laminar and calculate the pressure at the outlet end of the pipe and the average shear stress at the wall. (Relative density of glycerine = 1.26 and dynamic viscosity of glycerine = 0.9 Pa s) 20

(*b*) A very long cylindrical rod of 30 mm diameter is having one of its ends attached to a wall maintained at 500 °C. Entire length of the rod is exposed to atmosphere at 25 °C with convective heat-transfer coefficient of 25 W/m^2 K. Temperature along the length of the rod at (x_1) distance from the base is 400 °C and at (x_1 +10 mm) distance is 390 °C.

(i) Find the thermal conductivity of the rod.
(ii) Find the distance at which temperatures are measured.
(iii) Plot the graph on a plain paper showing the variation of temperature along the length of the rod.

Consider the following relation :

$$\frac{T - T_\infty}{T_b - T_\infty} = e^{-mx}, \text{ where } m = \sqrt{\frac{hP}{kA}}$$ 20

(*c*) Give general specifications of engine in terms of its power ratings and swept volume for any commonly used two-wheeler and four-wheeler vehicle segment. Why now-a-days multiple inlet and multiple exhaust valves are preferred in engine system of a car over earlier conventional single inlet and single exhaust valve? Also find out for a four-stroke, four-cylinder SI engine operating at 4000 r.p.m., how many number of times the spark will trigger in one minute. 20

3. (*a*) A furnace is shaped like a long equilateral triangular duct whose side is 1 m. The base surface has an emissivity 0.7 and is maintained at 600 K. The heated left-side surface of emissivity 1.0 is maintained at 1000 K. The right-side surface is fully insulated. Determine the rate at which the energy must be supplied to the heated side externally per unit length of the duct in order to maintain the given conditions. [Take $\sigma = 5.67 \times 10^{-8}$ W m^{-2} K^{-4}] 20

(*b*) Comfort condition for a human being is 20 °C DBT with relative humidity of 50%. Atmospheric conditions at two places are given below during peak summer:

Place	DBT	Relative Humidity
Jaisalmer	45 °C	10%
Chennai	35 °C	80%

(i) Draw the processes in a plain paper applicable to convert the atmospheric condition air to comfort condition.
(ii) Suggest suitable air-conditioning devices to achieve these processes.
(iii) Determine the quantity of moisture needed to be added/removed per kg of air in these places.
[Psychrometric Chart is placed at the end] 20

(*c*) State various losses considered by actual cycle analysis of IC engines. Discuss any one of them in detail. 20

4. (*a*) For the purpose of project calculations, the total cost of moving a fluid over a distance by pipeline, at a steady flow rate Q, can be broken down into two items. First, the manufacture, laying and maintenance of the pipeline are represented by the cost C_1, which is proportional to D^3 [D = diameter of the pipe). The second item C_2 depends solely upon the energy required to pump the fluid. A preliminary design study for a particular project showed that the total cost was a minimum for D = 600 mm. If fuel prices are increased by 150%, and assuming only C_2 is affected, make a revised estimate of the optimum pipe diameter. 20

(*b*) A refrigeration unit of 250 TR (1 TR = 3.5 kJ/s) capacity using R-12 as the refrigerant operates between –10 °C and 35 °C as evaporator and condenser temperatures respectively. Enthalpy of the refrigerant entering the evaporator is same as saturated liquid enthalpy at the condenser outlet. Dry saturated vapour leaves the compressor. Find the following:

(i) Mass flow rate of the refrigerant required
(ii) Power required to run the compressor assuming isentropic compression
(iii) COP of the unit
(iv) Carnot COP
(v) Heat rejected by the condenser

Refer the following property tables:

T (°C)	P (bar)	V_f (m³/kg)	V_g (m³/kg)	h_f (kJ/kg)	h_{fg} (kJ/kg)	h_g (kJ/kg)	S_f (kJ/kg K)	S_g (kJ/kg K)
–10	2.191	0.000701	0.0821	26.87	156.32	183.19	0.1080	0.7019
35	8.48	0.000786	0.0207	69.56	131.89	201.45	0.2559	0.6839

20

(*c*) What are the different types of work in thermodynamics? State whether flow work is path function or point function. Write the steady flow energy equation for a single stream entering and single stream leaving a control volume. Also discuss steady flow energy equation for the following engineering systems: 20

(i) Throttling device
(ii) Compressor

SECTION—B

5. (*a*) Discuss why Pelton turbines are unsuitable for low heads. 12

(*b*) Mention the various advantages and disadvantages of the pulsejet engine and also draw the theoretical and actual pulsejet cycle on a P-V diagram. 12

(*c*) Dry saturated steam at 40°C enters the surface condenser of a 500 MW thermal power plant having specific steam consumption of 3 kg/kWh. This steam is cooled by the water entering at 25 °C. Minimum terminal temperature difference in the condenser is 7 °C. Water flows through the tubes of internal diameter 3.75 cm and thickness of 3 mm with a velocity of 1 m/s. The overall heat-transfer coefficient of the condenser, U_0 =1500 W/m K. Determine the following for the condenser:

(i) Mass flow rate of water required in kg/s
(ii) Number of tubes required for the given heat-transfer rate
(iii) Length of each tube

Assume correction factor = 1
Density of water = 1000 kg/m^3
Specific heat of water = 4.2 kJ/kg K
Latent heat of condensation (h_{fg}) = 2407 kJ/kg
Condensed water leaves at saturated condition. 12

(*d*) State the factors affecting the performance efficiency of solar PV cell. An inventor claims that his 1 m^2 size PV cell panel is capable of producing 2 kW of instantaneous power for a given location in the Indian context. Is his claim valid? Justify.
Assume suitable data wherever necessary. Consider the normally available PV cell efficiency as 15%. 12

(*e*) With reference to wind turbine, what is tip speed ratio? State its significance. For a wind turbine meant for generation of electricity, how many number of blades are desirable in general? If the tip of a wind rotor blade is travelling at 45 m/s and wind speed is 32 km/h, obtain the tip speed ratio. 12

6. (*a*) What are surging and stalling in axial flow compressors? Explain briefly how they are developed and their effects. 20

(*b*) A coal-based 660 MW capacity thermal power plant is having overall efficiency of 42%. It uses 600 kg/s of steam for running the turbine. Coal used in the power plant is having calorific value of 10000 kJ/kg. Fuel to air ratio is 1 : 10 for combustion in the boiler. Find the following: 20

(i) Specific steam consumption in kg/kWh
(ii) Mass flow rate of coal required in Tph (Tonnes per hour)
(iii) Mass flow rate of air required for combustion in kg/s
(iv) Heat required to be supplied to generate one unit of power (in kJ/kWh)
(v) Coal required to be supplied to generate one unit of power (in kg/kWh)

(*c*) A hotel industry intends to replace its existing electric water heating system with a solar water heating system. The requirement of hot water is around 5000 litres per day. The proposed solar collector area is around 100 m^2 and the average solar radiation falling can be considered as 500 W/m^2. If the collector efficiency is 60%, estimate the reduction in electric bill of the hotel on a yearly average basis. Consider cost of electricity as ₹ 6/kWh. Make suitable assumptions wherever required. Consider average value of length of the day as 10 hours. Also estimate temperature rise of water for given radiation and collector efficiency data. Assume Indian context. Assume electric geyser efficiency as 95%. 20

7. (*a*) A Parsons turbine runs at 400 r.p.m. with 50% reaction and it develops 75 kW of power per unit mass of steam flow per second. The exit angle of the blades is 20° and the steam velocity is 1.4 times the blade velocity. Find the blade velocity and inlet angle of the blades. 20

(*b*) (i) Compare the supercritical Rankine cycle and subcritical Rankine cycle used in coal-based thermal power plants.

(ii) How do you estimate the theoretical minimum air required for combustion by knowing the ultimate analysis of the coal? Molecular weight of C, O, H and S can be taken as 12, 16, 1 and 32 units respectively. 20

(*c*) What is the approximate composition of biogas? State any two factors that govern the biogas production. A family living in a village having 5 cows is

interested to set up a biogas plant to meet its cooking requirements. The family has 5 adult persons. Estimate its biogas requirements on daily basis. Also work out the cow dung requirement on daily basis and also find out whether the number of cows available with family is sufficient to meet its requirement.

The following data may be useful: 20

Collectable cow dung per cow = 7 kg (approx.)

Percent of solid mass in cow dung with balance moisture = 18%

Gas yield per kg of dry matter of cow dung = 0.34 m /kg of dry mass

Gas requirement for cooking = 0.227 m^3/person/day

8. (*a*) What do you mean by Net Positive Suction Head (NPSH)? Find the height from the water surface at which a centrifugal pump may be installed to avoid cavitation when atmospheric pressure = 101 bar, vapour pressure = 0.022 bar, losses in suction pipe = 1.42 m, effective head of pump = 49 m and cavitation factor = 0.115. 20

(*b*) Economizer of a power boiler operating at 150 bar pressure receives 500 kg/s of water from boiler feed pump with specific enthalpy of 340 kJ/kg. Superheated steam leaves the boiler at 550 °C with specific enthalpy of 3448.6 kJ/kg. Efficiency of the boiler is 90% and calorific value of the coal used is 10000 kJ/kg. Find the following:

(i) Heat added in economizer, evaporator and superheater in kJ/s

(ii) Percentage of heat added in economizer, evaporator and superheater out of total heat

(iii) Rate of coal consumption in kg/s

Also draw T-s plot showing the position of different components and heat added.

For 150 bar pressure, use the following table :

P_s (bar)	T_s (°C)	h_f (kJ/kg)	h_{fg} (kJ/kg)	h_g (kJ/kg)
150	324.24	1610.5	1000	2610.5

20

(*c*) Explain the working principle of solar cooker. What are the challenges in making solar cooker more popular? Also describe the thermal energy storage system of solar energy. 20

MECHANICAL ENGINEERING Paper II

Time Allowed: Three Hours **Maximum Marks: 300**

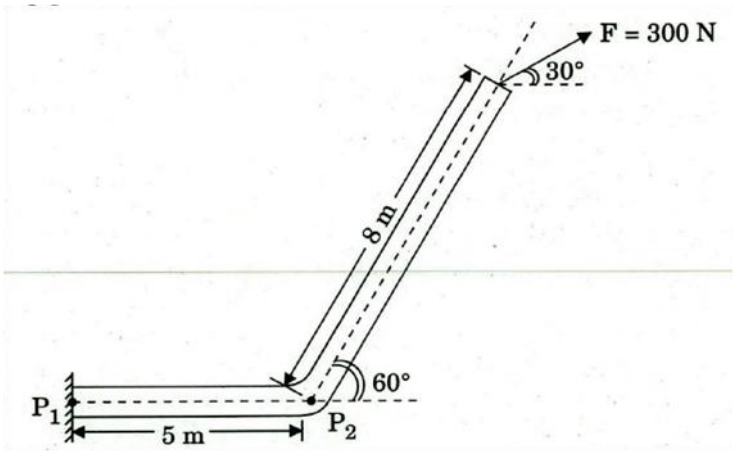
Question Paper Specific Instructions

***Please read each of the following instructions carefully before attempting questions*:**

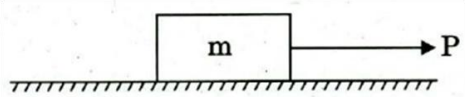
*There are **EIGHT** questions divided in **TWO** sections.*
*Candidate has to attempt **FIVE** questions in all.*
*Questions No. **1** and **5** are compulsory and out of the remaining, **THREE** are to be attempted choosing at least **ONE** question from each section.*
The number of marks carried by a question/part is indicated against it.
Answers must be written in the medium authorized in the Admission Certificate which must be stated clearly on the cover of this Question-cum-Answer (QCA) Booklet in the space provided. No marks will be given for answers written in a medium other than the authorized one.
Assume suitable data, if considered necessary and indicate the same clearly.
Unless otherwise mentioned, symbols and notations carry their usual standard meanings.
Attempts of questions shall be counted in sequential order. Unless struck off, attempt of a question shall be counted even if attempted partly. Any page or portion of the page left blank in the Question-cum-Answer Booklet must be clearly struck off
*Answers must be written in **ENGLISH** only.*

SECTION A

Q1. (a) (i) A flue pipe in a furnace system is rigidly attached to the furnace wall at P_1 as shown in the figure below. Compute the moments at points P_1 and P_2 when a force of 300 N is acting at the end of the pipe. 6



(ii) Consider a solid block of mass 'm' resting on a horizontal surface. When the mass is subjected to a horizontal force 'P' it will experience a frictional force resisting the motion. Draw and show the variation of frictional force F vs. applied force P even if it continues to shift from no motion (static friction) domain to motion domain (kinetic friction). 6



(b) Draw and show the bending moment diagram and shear force diagram of a beam of length L subjected to a uniformly distributed loading for the following boundary conditions:

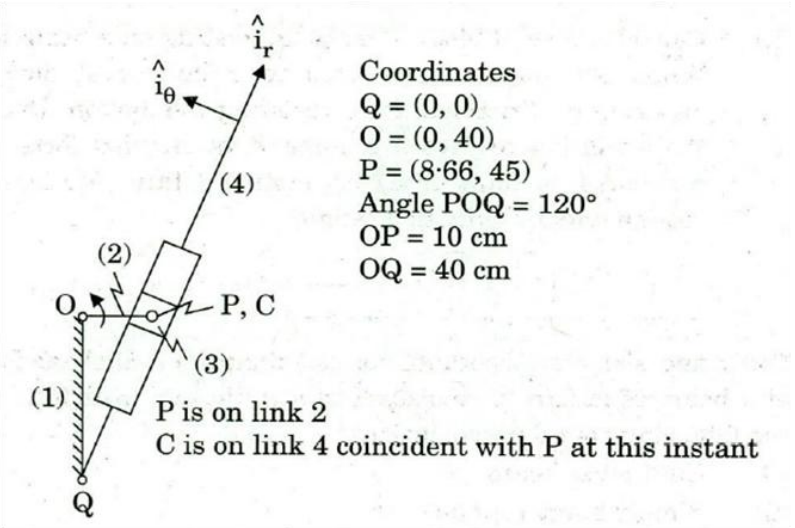
(i) Cantilever beam
(ii) Simply supported beam
(iii) Beam with both ends fixed
(iv) Beam with one end simply supported and a propped support at $1/4^{th}$ L from the other end 12

(c) (i) Distinguish and differentiate between machine and mechanism. Define the term Inversion of a kinematic chain.
(ii) Discuss about the possible inversions (with figures) of a four bar chain. 12

(d) Derive the equation for the resultant unbalanced force at any instant of a reciprocating mass of a slider crank mechanism. 12

(e) In a pair of mating spur gears, the pitch-diameter of smaller gear is 120 mm. The pair is of standard gear involute having module as 8. If the transmission ratio between the gears is 4 : 3, then find out $2 \times 6 = 12$
(i) Number of teeth on gear,
(ii) Number of teeth on pinion,
(iii) Addendum,
(iv) Dedendum,
(v) Whole depth, and
(vi) Clearance.

Q2. (a) Compute the velocity and acceleration of the slider in the quick return mechanism shown in the figure below, if the crank rotates at 30 rpm. 15



(b) (i) Draw and show the variation of centrifugal force and controlling force of a governor.
(ii) Define Stability, Sensitivity, Isochronism and Hunting in a governor. 15

(c) The data for 2 sets of spur gears are given below

	Set-1	Set-2
Pressure angle	20°	20°
No. of teeth in Large gear	40	50
No. of teeth in Pinion	20	13
Module	10 mm	10 mm
Addendum	1 module	1 module

Check for the occurrence of Interference. If it occurs, what is the pressure angle to correct it? 15

(d) (i) A single degree of freedom system is subjected to an external harmonic

force $F(t) = F_0 \sin \omega t$. Define magnification factor (MF) and plot it as a function of damping factor as it varies with respect to frequency ratio. 8

(ii) A machine part having a mass of 2.5 kg vibrates in a viscous medium. A harmonic exciting force of 30 N acts on the part and causes a resonant amplitude of 14 mm with a period of 0.22 seconds. Find the damping coefficient. 7

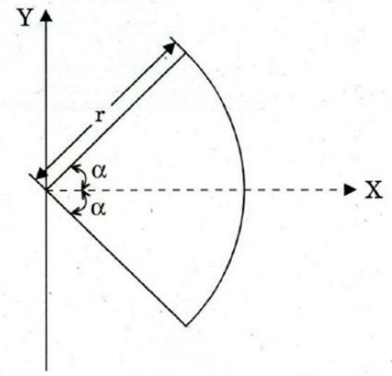
Q3. (a) (i) Define, discuss and differentiate: 7

(A) Centers of mass vs Centroid

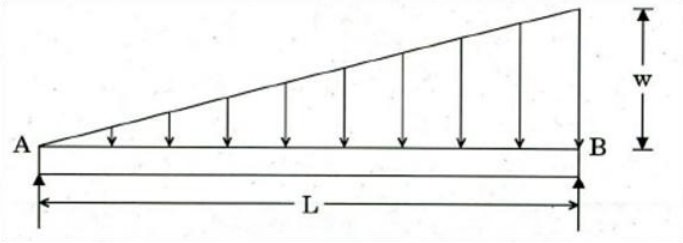
(B) Mass Moment of Inertia vs Area moment of inertia

(C) Centroid of Lines, Areas and Volumes

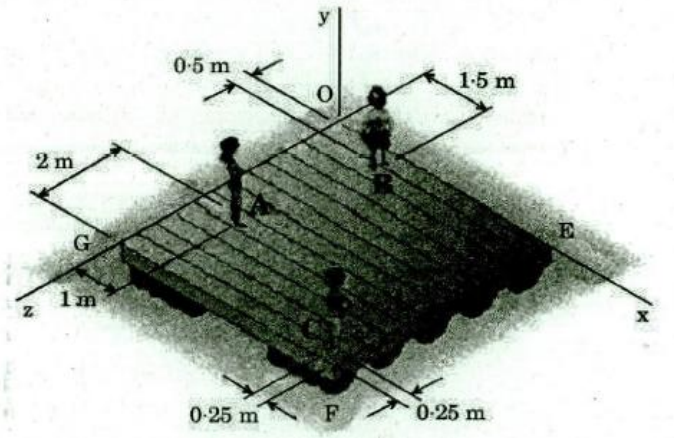
(ii) Locate the centroid of a circular arc as shown in the figure below: 8



(b) Draw the Shear Force Diagram and Bending Moment Diagram of a simply supported beam carrying a uniformly varying load from zero at one end to 'w' per unit length at the other end. Compute the maximum B.M and its location. 15



(c) (i) Three children are standing on a 5 m × 5 m raft as shown in the figure below:



The weights of the children at points A, B and C are 375 N, 260 N and 400 N, respectively. Determine the magnitude and the point of the resultant of their weights. 10

(ii) In a two dimensional system acted by various forces as specified below :

- forces are collinear
- forces are concurrent at a point
- forces are parallel to each other
- general

Draw the free body diagram and equation defining them. 5

(d) Two shafts of the material and of same lengths are subjected to same torque. If the first is of a solid circular section and the second shaft is of hollow circular section, whose internal diameter is 2/3 of the outside diameter and the maximum shear stress developed in each shaft is the same, compare weights of the shafts. 15

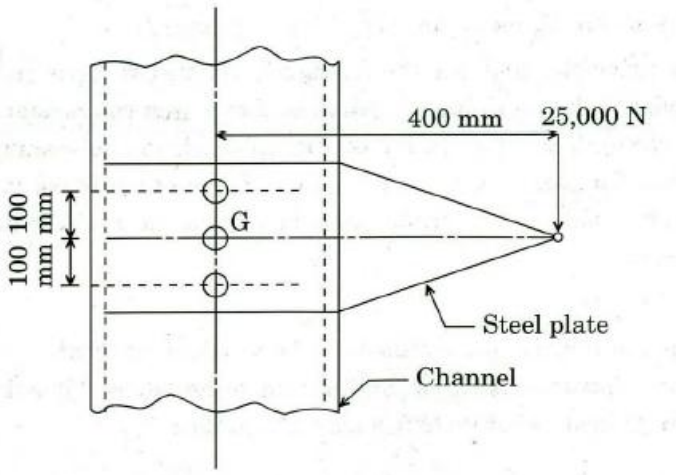
Q4. (a) Differentiate between uniform pressure and uniform wear theory. What would you conclude, about the effect over friction radius, under following two conditions of operation of a clutch, considering uniform pressure theory and uniform wear theory in both the conditions. 20

(i) Outer Radius – 100 mm Inner Radius – 90 mm

(ii) Outer Radius – 100 mm Inner Radius – 25 mm

(b) Design a flywheel for a single cylinder four-stroke diesel engine, made of cast iron, whose allowable strength is 20 MN/m^2, The engine is running at a speed of 1400 r.p.m. and producing 5 kW of power. Maximum peripheral speed of the flywheel may be up to 24 m/sec. Coefficient of fluctuation of energy may be taken as 2.2 and coefficient of speed fluctuation as 0015. Density of cast iron may be taken as 7000 kg/m^3. (The effect of overhang of the flywheel on the end may be neglected.) 20

(c) Three M20 bolts are used to connect a steel plate with a channel section structural member as shown in the figure. The material of the bolt is 50C4 with σ_u = 660 MPa and σ_y = 460 MPa. Determine the factor of safety, if the plate carries a load of 25,000 N at its end. Take area of M20 bolts as 245 mm^2.



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SECTION B

Q5. (a) Define unit cell of a space lattice. Derive the effective number of lattice points in the unit cell of cubic lattices. Calculate the packing efficiency and density of silicon which has diamond cubic structure. Use the following properties for silicon:

Atomic No. = 14

Atomic Mass Unit = 1.66×10^{-27} kg

Lattice Parameter = 50431×10^{-10} m

Assume radius of Si atom in diamond cubic structure to be $\left(\frac{\sqrt{3}}{8}\right)$ times the lattice parameter. 12

(b) Define a 'sensor'. Describe the following performance terms related to a sensor: 12

(i) Accuracy
(ii) Sensitivity
(iii) Hysteresis error
(iv) Non-linearity error
(v) Resolution

(c) What is the significance of Ernst and Merchant theory in study of mechanics of chip formation in machining operation?

Using its principle, find out the cutting force, thrust force and shear force applied in a machining operation of a cast iron component, whose ultimate strength is 370 MPa and coefficient of friction between tool and chip is 0-55. The depth of cut is 35 mm and feed of cut is 0.3 mm. The normal rake angle and principal cutting edge angle are 12° and 30°, respectively. 12

(d) What are the important ingredients (elements) of an FMS? In what kind of manufacturing scenario, is it best to be employed? For the same case, or in general, enlist its four major advantages. 12

(e) A project has seven activities, each with totally deterministic completion time and involved cost. These activities with other related data are as given in the table below.

Activity	Immediate Predecessor	Normal Time (days)	Normal Cost (₹ in lakhs)	Crash Time (days)	Crash Cost (₹ in lakhs)
A	—	9	70	6	100
B	A	6	60	4	80
C	A	7	80	4	89
D	A	5	30	4	32
E	B, C	4	70	3	85
F	C, D	6	35	5	43
G	E, F	7	40	4	85

Each day of early completion of the project yields saving in administrative cost of ₹ 2 lakhs and an additional profit of ₹ 5 lakhs.

Find out the most economical completion time for the project assuming that crashing cost increases linearly with the decrease in activity duration. 12

Q6. (a) Define 'phase' of a system. Mention Gibbs' phase rule and describe the terms in it. Lead and tin have complete liquid solubility and limited solid solubility. Describe the binary phase diagram involving lead and tin. Explain how this phase diagram helps in identifying composition for electrical solder and plumbing solder. 15

(b) Describe different heat treatment processes of steels with the help of Iron-Carbon equilibrium diagram. On a T-T-T diagram of plain carbon steel, show the following processes and the resulting phases :

- Water quench to room temperature
- Hot quench to 300°C, hold for 5 h and water quench
- Hot quench to 450°C, hold for 1 h and water quench

On the same T-T-T diagram, show the Austempering and Martempering

processes. 15

(c) A manufacturer of textile dyes can use two different processing routes for producing a particular type of dye. Route 1 uses drying press A, and route 2 uses drying press B. Both routes require the same mixing vat to blend chemicals for the dye before drying. The following table shows the time requirements and capacities of these processes:

Process	Time Requirements (hour/kg)		
	Route 1	Route 2	Capacity (hour)
Mixing	2	2	54
Dryer A	6	0	120
Dryer B	0	8	180

Each kilogram of dye processed using route 1 uses 20 litres of chemicals, whereas each kilogram of dye processed on route 2 uses only 15 litres. The difference results from differing yield rates of the drying presses. Consequently, the profit per kilogram processed on route 1 is ₹ 500 and on route 2 is ₹ 650. A total of 450 litres of input chemicals is available. Write the constraints and objective function to maximize profits.

Use the graphic method to find the optimal solution, and also non-utilised part of the processes. 15

(d) A plant is capable of producing 10,000 units of an item in a year. Demand of this item is not increasing and is going to remain constant in future as well. Annual demand of this item is going to stay at 5,000 units. Set-up cost of ₹ 10,000 has to be incurred every time a new batch of this item is launched for production. Each unit of the item, after its manufacture, costs ₹320. Inventory carrying cost of the finished item is 10% of its cost when held in stock for one year.

Determine the economic production lot size and the number of batches to be taken each year for production assuming all these batches are to be of equal size. Also determine inventory cycle and production cycle (the time during which the plant shall be busy in an inventory cycle for producing the item) length. 15

Q7. (a) Time between failure of a machine is known to be exponential with mean value of 9000 hours (about 1 year of operation). The company issues one-year warranty on this machine.

What are the chances that a breakdown repair will be required from the company during the warranty period?

The machine has run without fail for 4,500 hours. What are the further chances of breakdown repair under warranty period? 20

(b) (i) Explain in brief, about the geometric characteristics of Flatness, Straightness, Roundness, Profile of a surface and Angularity. Also, show the symbols by which these are represented. 10

(ii) What are the different zones of an electric arc, generated for the electric arc welding process? Also explain their characteristics. 10

(c) (i) What are the various forging defects, which are likely to take place, because of the faulty forging process design? Explain about any five in brief. 10

(ii) What is Gating ratio? What is its importance for successful casting

operation? Also, explain its types with their respective suitabilities, with examples. 10

Q8. (*a*) (i) What is a Gating System? What are the different elements of it? Explaining Aspiration Effect', discuss which of the elements of the Gating System is mostly affected with it and what measures are taken to avoid it. 10

(ii) State how Standard Tolerance Grade, position of Tolerance zone, Upper deviation and Lower deviation, Tolerance class and Fit are designated. 10

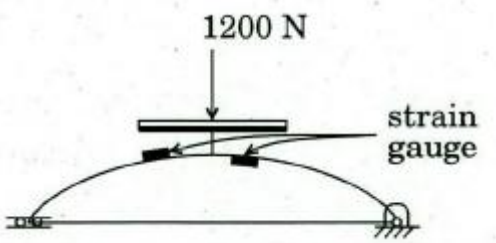
(*b*) A mechatronic platform scale is represented by the schematic shown below. It consists of two leaf springs with four strain gauges mounted, two on each leaf spring as shown. Leaf spring span is 300 mm and the cross-section is 30 mm × 4 mm.

The voltage corresponding to weight on the scale is measured as output Wheatstone bridge comprising of four strain gauges mentioned above. Gauge factor of these is 2.1 and they are mounted such that two will read tensile strain and other two will read transverse compressive strain. The Wheatstone bridge has four 100 Ω resistances and input voltage of 6 V. Determine the output voltage of the bridge corresponding to a weight of 1200 N on the weighing platform.

Properties of leaf spring material are

Modulus = 200 GPa

Poisson's ratio = 0.3



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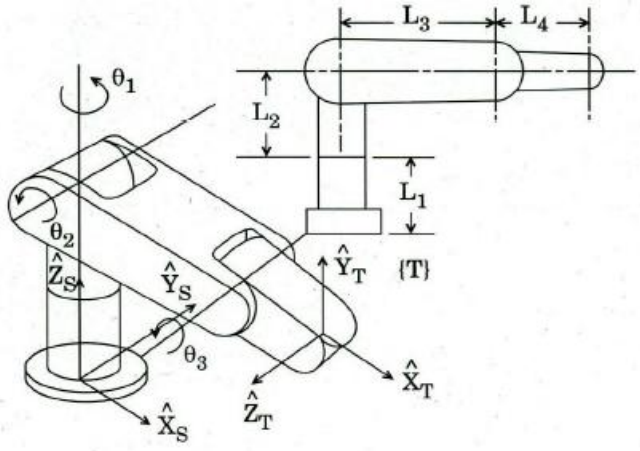
(*c*) Arm of 3 DOF manipulator is shown in the figure below. Joints 1 and 2 are perpendicular to each other and joints 2 and 3 are parallel. All joints are shown at their zero location and positive senses of the joint angles are indicated. Assign link frames {0} to {4} for the arm such that {0} represents frame {S} and {4} represents {T}. Make a table of D-H parameters and derive all the transformation matrices relating {0}, {1}, {2} and {3} frames.



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